

## LA-UR-14-28460

Approved for public release; distribution is unlimited.

Title:	Evaluated $^{239}\text{Pu}$ prompt fission neutron spectra and associated covariances for thermal to 30 MeV incident neutron energies
Author(s):	Neudecker, Denise
Intended for:	Nuclear Data Meetings at BNL: CSEWG/CIELO meeting, 2014-11-03 (Upton, New York, United States)
Issued:	2014-10-30

---

**Disclaimer:**

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the Los Alamos National Security, LLC for the National Nuclear Security Administration of the U.S. Department of Energy under contract DE-AC52-06NA25396. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

# Evaluated $^{239}\text{Pu}$ prompt fission neutron spectra and associated covariances for thermal to 30 MeV incident neutron energies

**Denise Neudecker**

**CSEWG/CIELO meeting 2014, 11/4**

In collaboration with/ thanks to:

- + ) T-2, LANL: P. Talou, T. Kawano, A.C. Kahler
- + ) P-27, LANL: T.N. Taddeucci, R.C. Haight, H.-Y. Lee
- + ) X, LANL: M. Rising, M.C. White, J. Lestone
- + ) ANL: D.L. Smith
- + ) IAEA Vienna: R. Capote

# MAIN AIM

---

Evaluation of the  $^{239}\text{Pu}$  prompt fission neutron spectrum for  $E_{\text{inc}} = \text{thermal} - 30 \text{ MeV}$ :

- Including *improved theoretical information* taking into account *expected physics processes*
- Including *new experiments & detailed experimental UQ*
- Right now, *benchmarking ongoing*



# The evaluated results take into account physics processes.

Physics  
Processes

Theory

Experiment

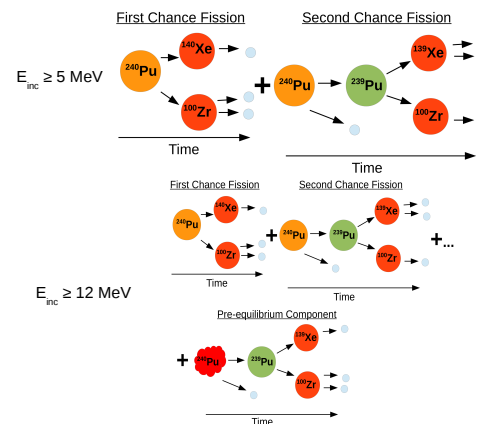
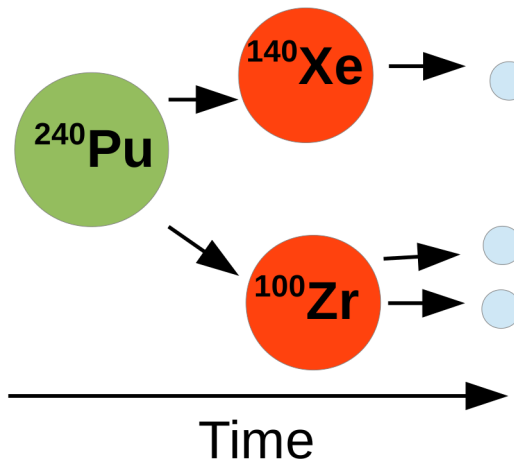
Results

Benchmarks

Summary

$$E_{inc} \leq 5 \text{ MeV}$$

## First Chance Fission



# The evaluated results take into account physics processes.

Physics  
Processes

Theory

Experiment

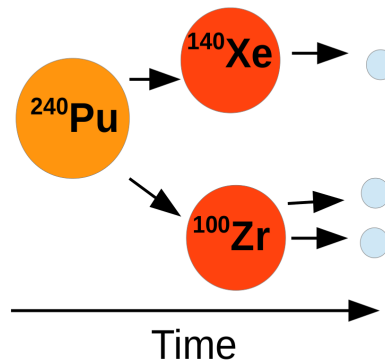
Results

Benchmarks

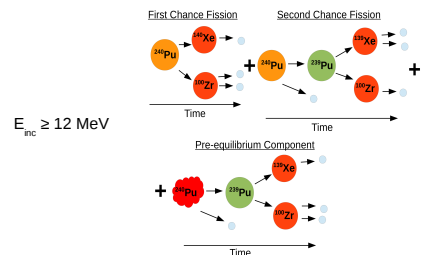
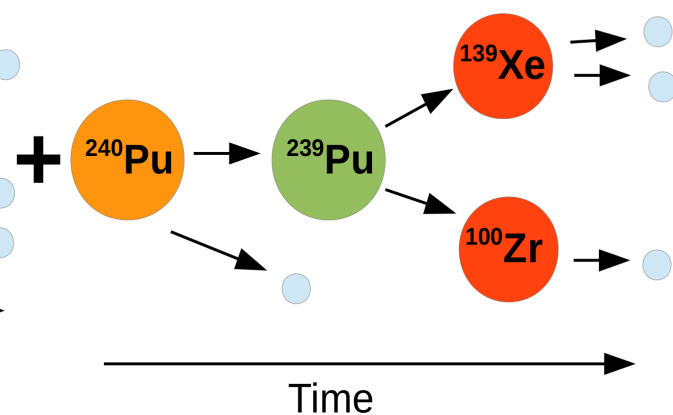
Summary

$$E_{inc} \geq 5 \text{ MeV}$$

First Chance Fission



Second Chance Fission



# The evaluated results take into account physics processes.

Physics  
Processes

Theory

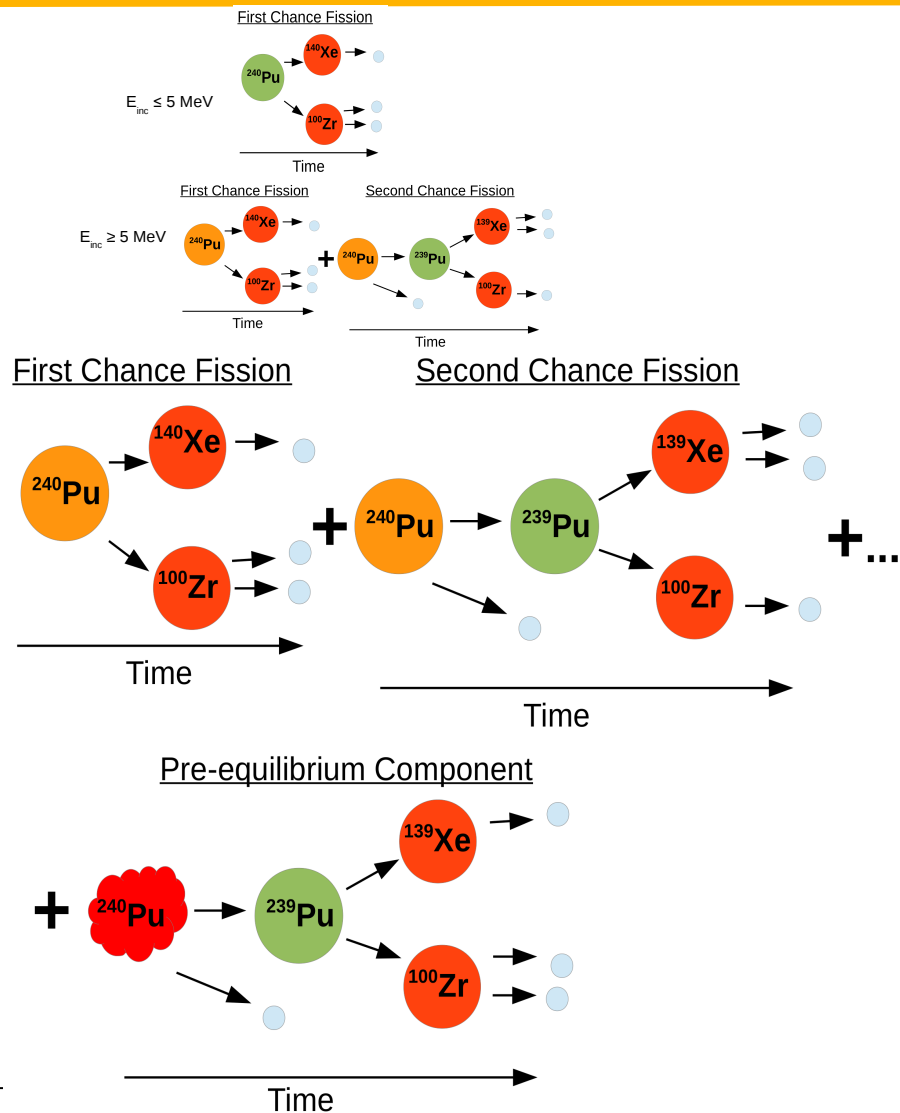
Experiment

Results

Benchmarks

Summary

$$E_{inc} \geq 12 \text{ MeV}$$



# The Los Alamos model and the exciton model are used.

Physics  
Processes

Theory

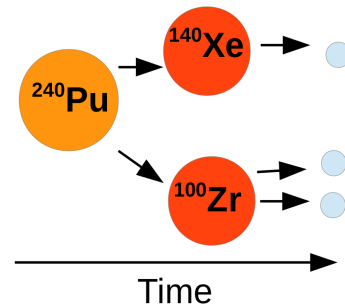
Experiment

Results

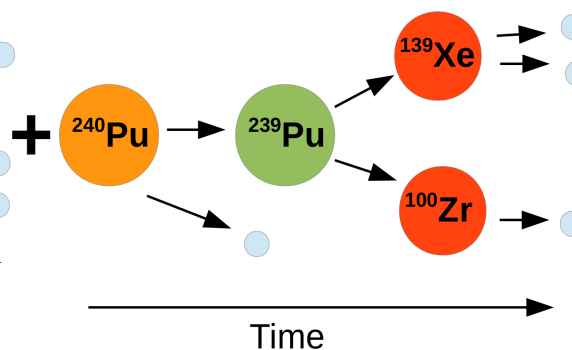
Benchmarks

Summary

First Chance Fission



Second Chance Fission

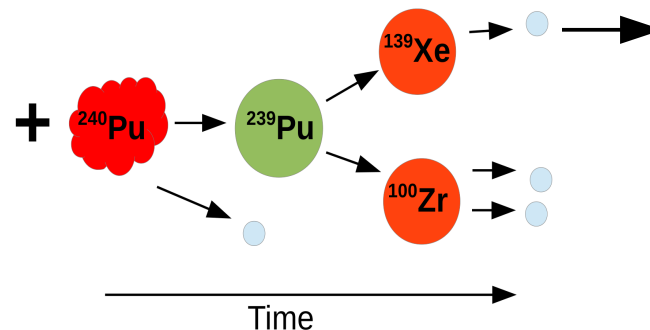


The **LAM** is used for **compound nucleus processes.**

$$\chi(E) \propto p_f^{(1)} \bar{\nu}_1 \chi_1(E) + p_f^{(2)} [\phi_1(E) + \bar{\nu}_2 \chi_2(E)]$$

$$+ p_f^{(3)} [\phi_1(E) + \phi_2(E) + \bar{\nu}_3 \chi_3(E)] + \dots$$

Pre-equilibrium Component



The **exciton model** is used for the **pre-equilibrium component.**

# The LAM PFNS are a weighted sum of average light and heavy fission fragment PFNS.

Physics  
Processes

$$\chi_1(E) = \frac{\overline{v}_{1L} \chi_{1L}(E, T_{mL}, a_L, b, s, \dots) + \overline{v}_{1H} \chi_{1H}(E, T_{mH}, a_H, b, s, \dots)}{\overline{v}_{1L} + \overline{v}_{1H}}$$

Theory

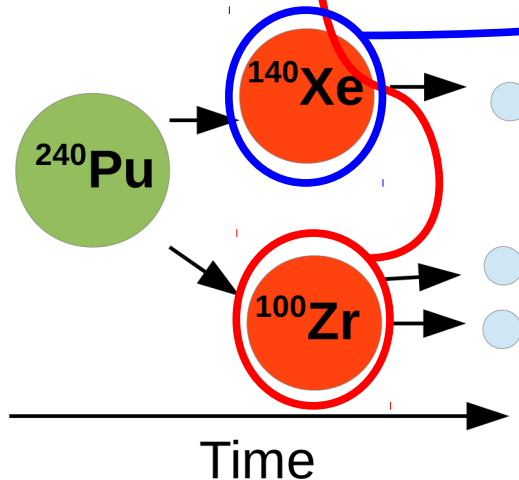
Experiment

Results

Benchmarks

Summary

First Chance Fission



- We extended the LAM by:
- *Anisotropy* in the neutron emission in the cms frame (parameter  $b$ )
  - $\overline{v}_{1L} \neq \overline{v}_{1H}$  and  $T_{mL} \neq T_{mH}$
  - *Temperature distribution* by Hambsch (parameter  $s$ ).

# We extended the original LAM and considered $E_{inc}$ -dependent of processes involved:

Physics  
Processes

→ *Multi-chance fission* considered.

Theory

→ *Pre-equilibrium component* considered.

Experiment

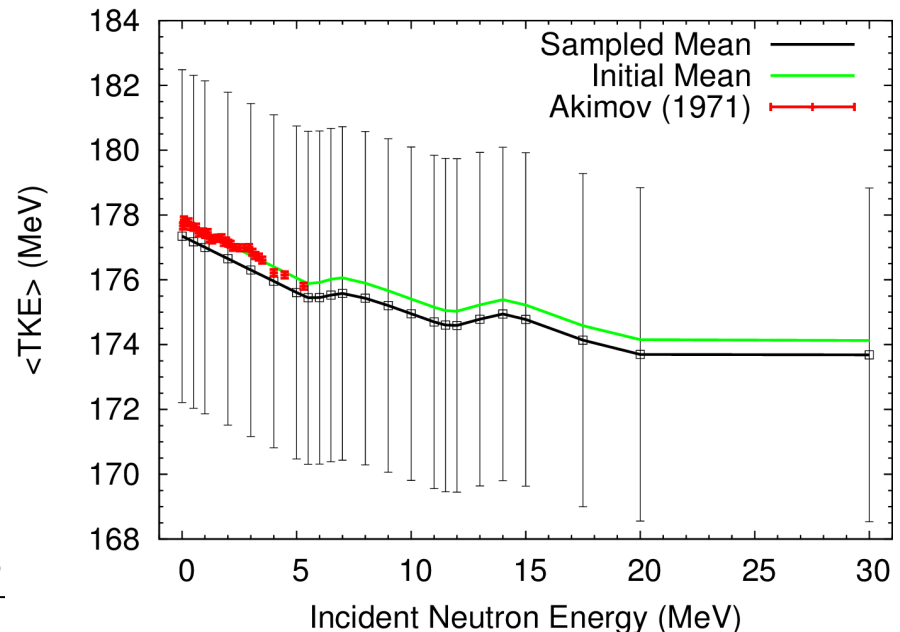
→  *$E_{inc}$ -dependent parametrization of  $\langle TKE \rangle$  and  $\langle E_r \rangle$*  of Lestone and Madland used.

Results

→ *Fission barrier parameters fitted* to reproduce ENDF/B-VI.0 fission probabilities.

Benchmarks

Summary



# The experimental data base:

Physics  
Processes

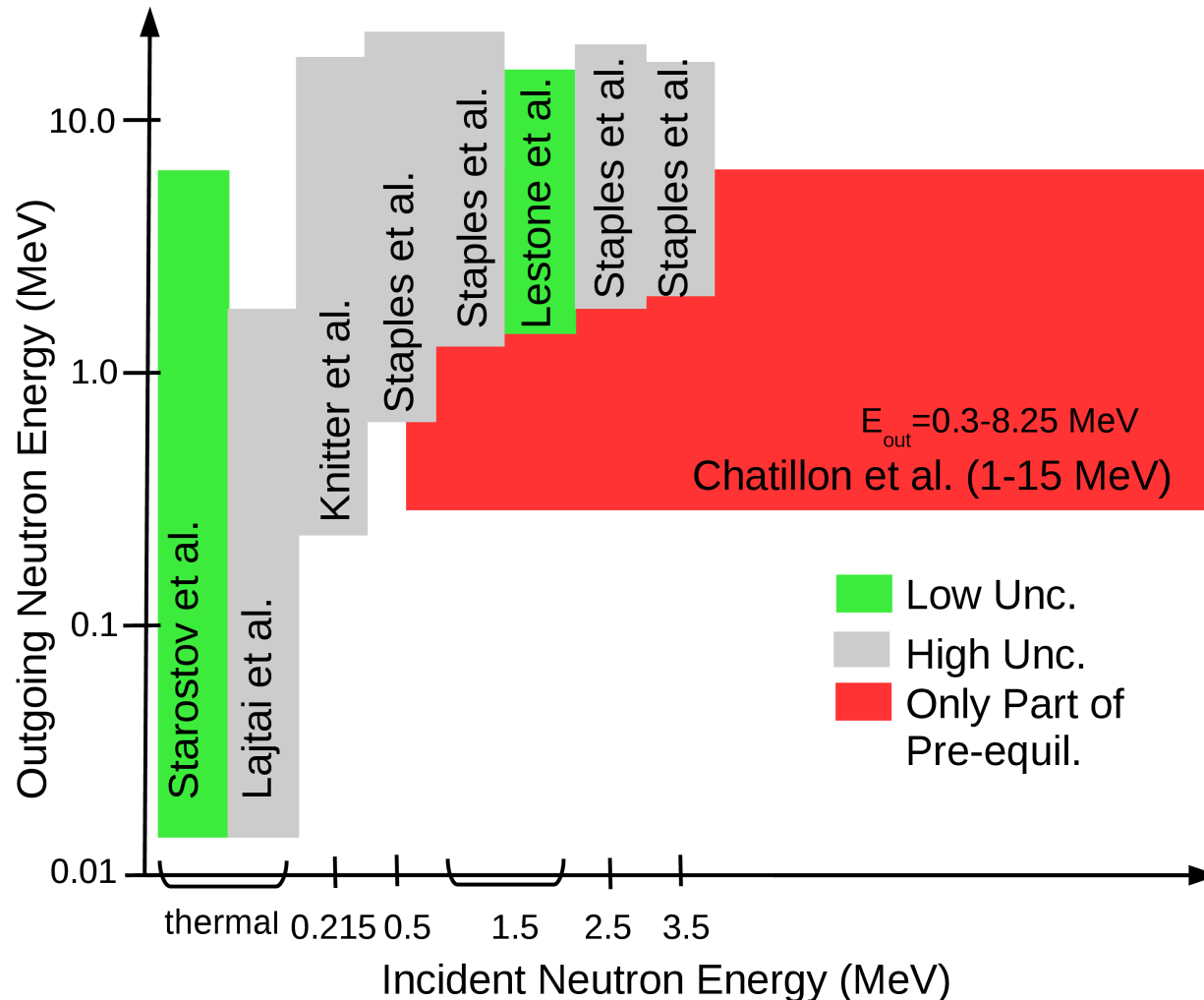
Theory

**Experiment**

Results

Benchmarks

Summary



# Experimental Uncertainties are estimated in detail.

Physics  
Processes

Theory

**Experiment**

Results

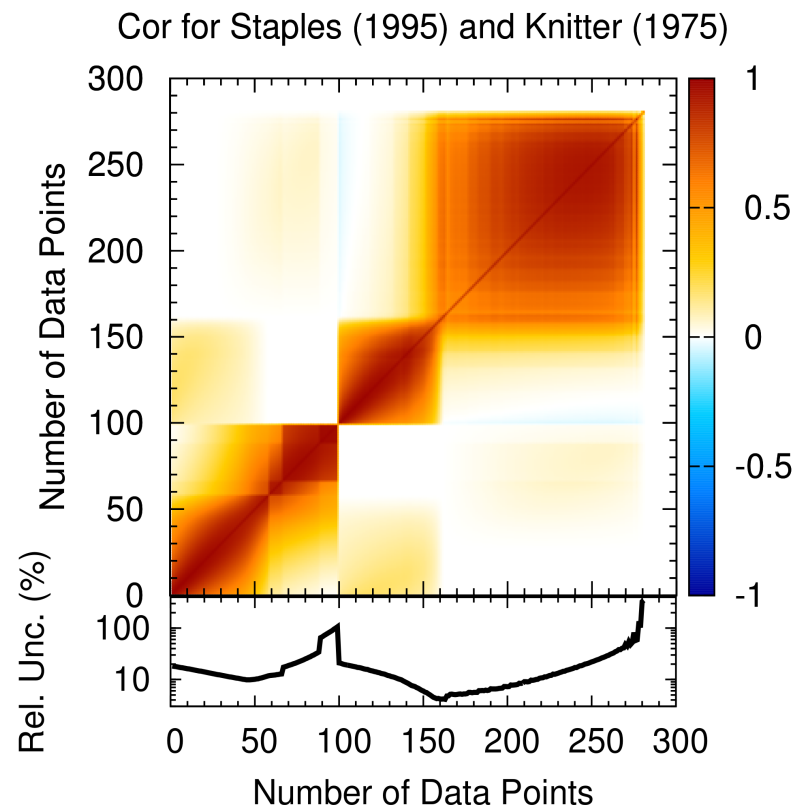
Benchmarks

Summary

→ Experimental uncertainties were estimated by partitioning into *partial unc. sources*.

→ Correlation matrices were estimated for partial unc.

→ *Correlations between two different experiments* were estimated in the same way.





# Selected results:

Physics  
Processes

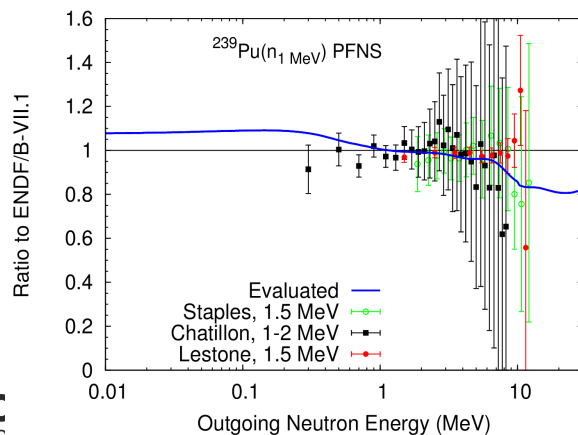
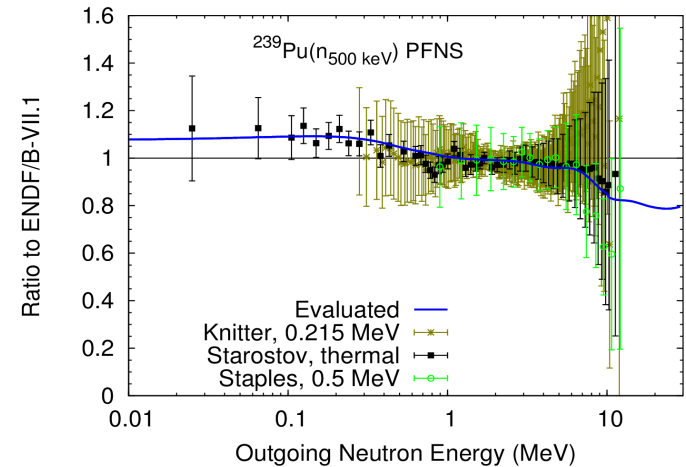
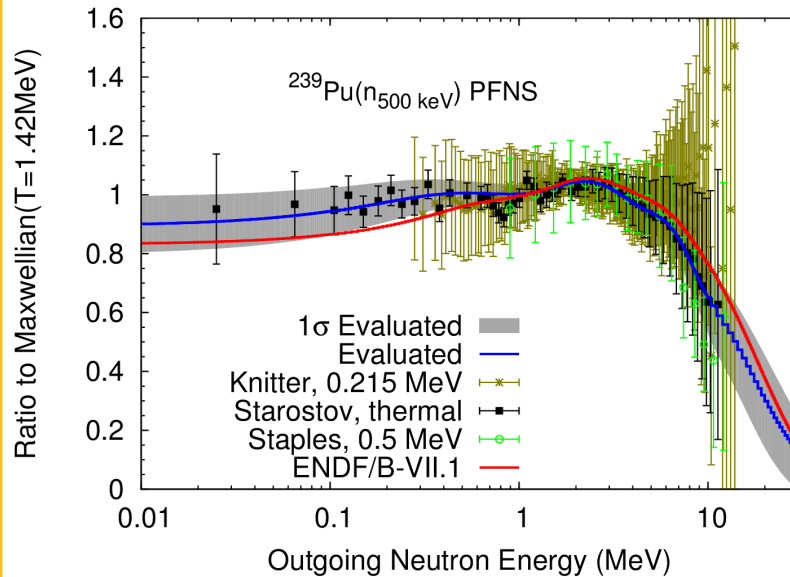
Theory

Experiment

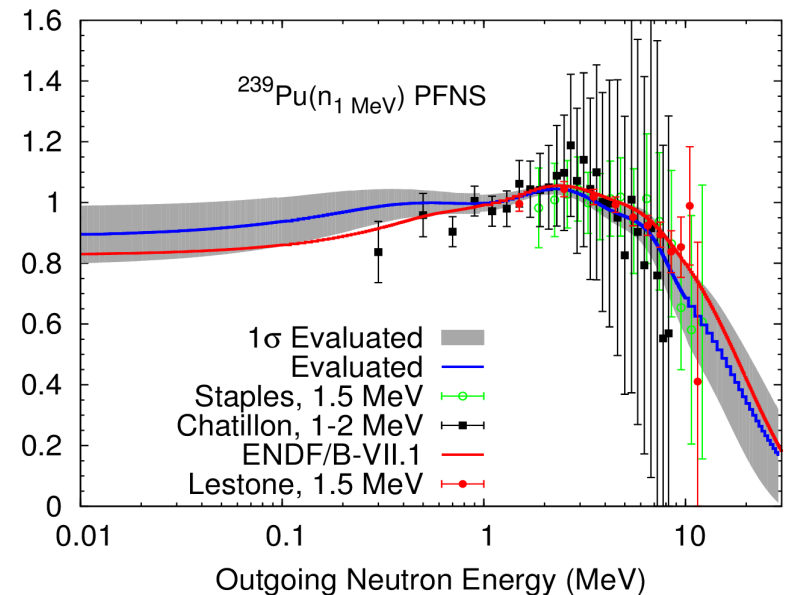
**Results**

Benchmarks

Summary



Ratio to Maxwellian ( $T=1.42\text{ MeV}$ )



# Selected results:

Physics  
Processes

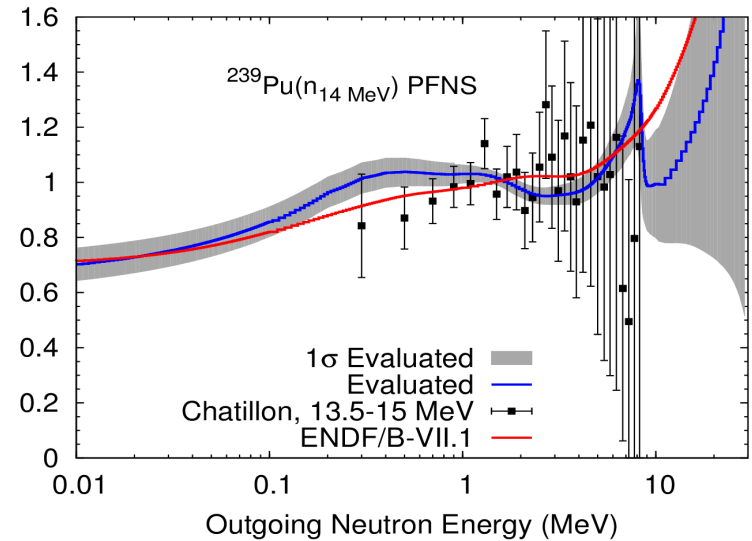
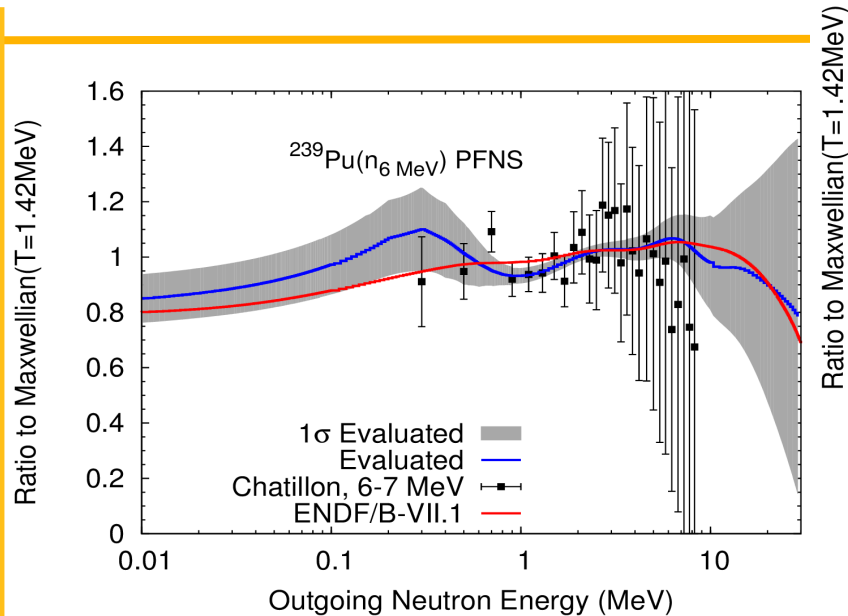
Theory

Experiment

**Results**

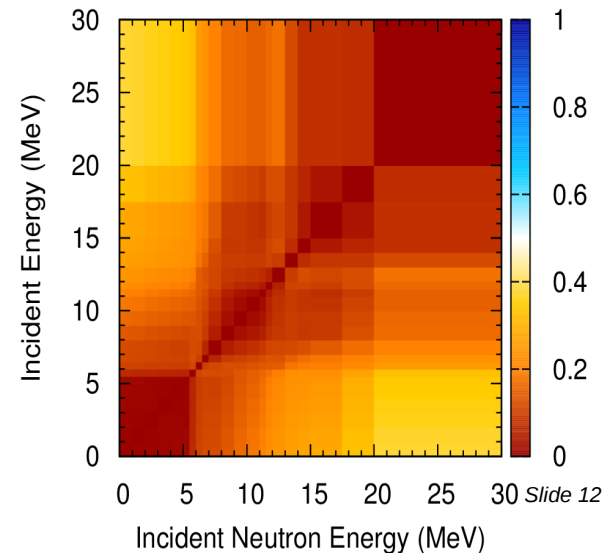
Benchmarks

Summary



We provide evaluated  
covariances for all incident  
neutron energies.

Mean of difference between correlations of different  $E_{\text{inc}}$



# Selected results:

Physics  
Processes

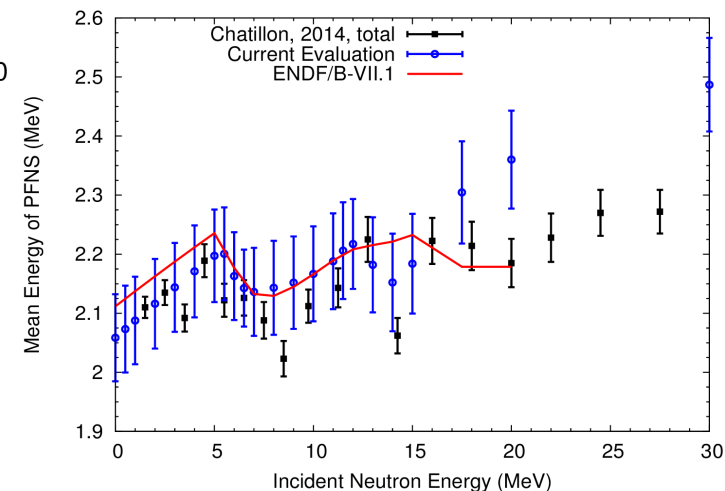
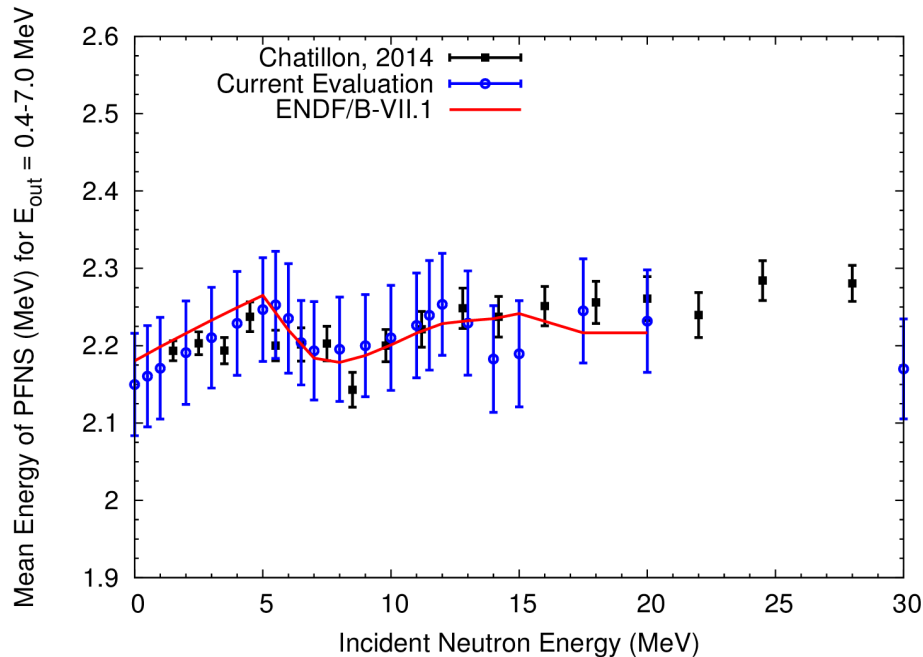
Theory

Experiment

**Results**

Benchmarks

Summary



# Selected benchmark results of Mike Rising using a similar evaluation:

Physics  
Processes

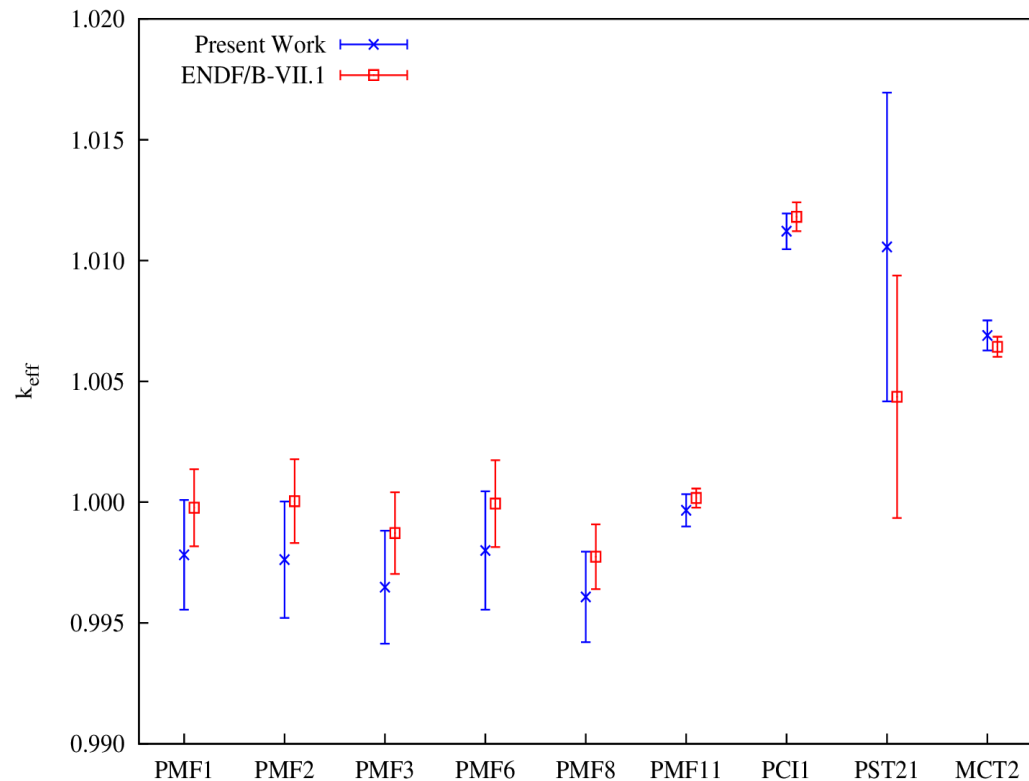
Theory

Experiment

Results

**Benchmarks**

Summary



More in talk of A.C. Kahler.

# To-Do:

Physics  
Processes

Theory

Experiment

Results

**Benchmarks**

Summary

→ Study differential data of A. Smith recently recovered by the IAEA

→ **Adjustment of data** using benchmark data. (e.g.,  $^{239}\text{Pu}(n,2n)/^{239}\text{Pu}(n,f)$  and  $^{241}\text{Am}(n,2n)/^{239}\text{Pu}(n,f)$  )

→ **Further benchmark** tests.

# Summary:

Physics  
Processes

Theory

Experiment

Results

Benchmarks

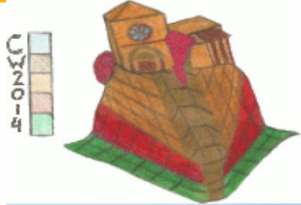
**Summary**

## Evaluation of the $^{239}\text{Pu}$ prompt fission neutron spectrum for $E_{\text{inc}} = \text{thermal} - 30 \text{ MeV}$ :

- Including *improved theoretical information* taking into account *expected physics processes*
- Including *new experiments & detailed experimental UQ*
- Right now, *benchmarking ongoing*



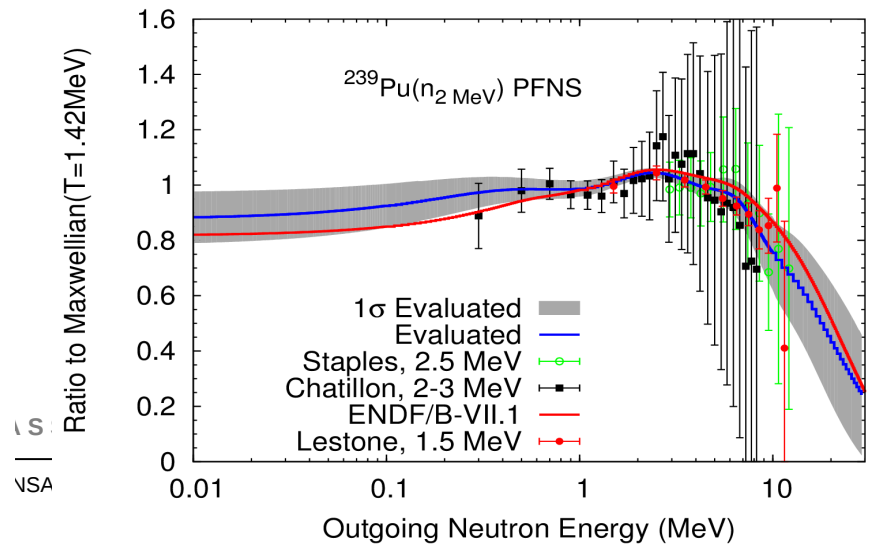
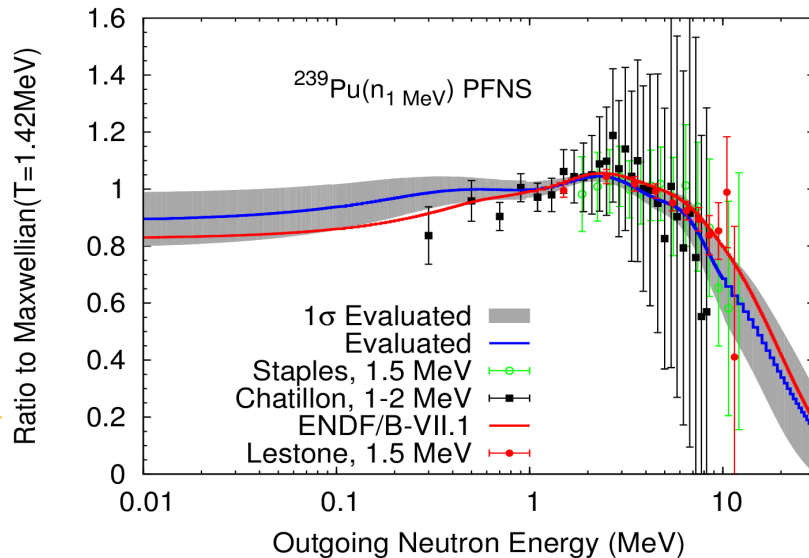
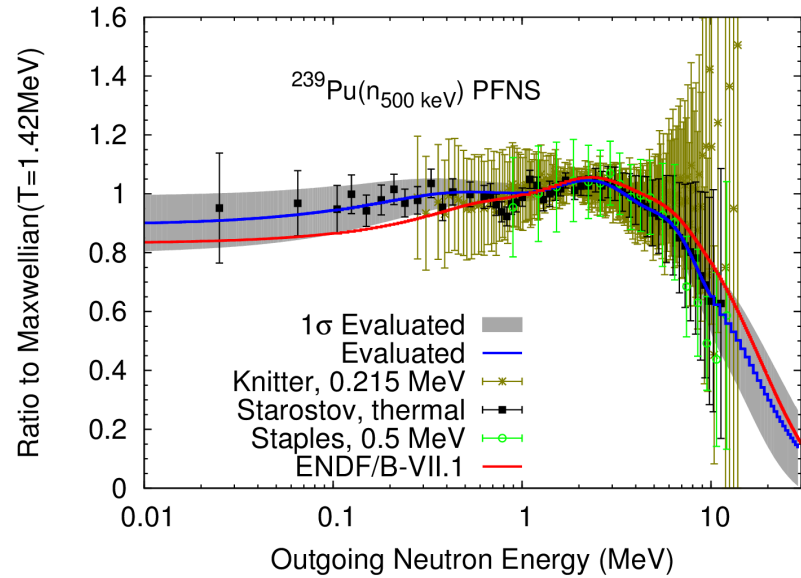
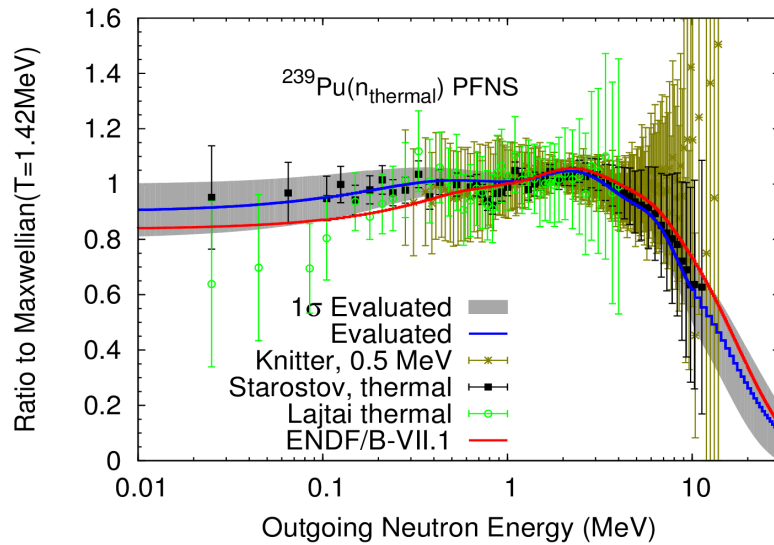
# CW2014 conference proceeding will appear in **Nuclear Data Sheets 123, January 2015**



**International Workshop on  
Nuclear Data Covariances**  
**April 28 – May 1, 2014**  
**Santa Fe, New Mexico, USA**

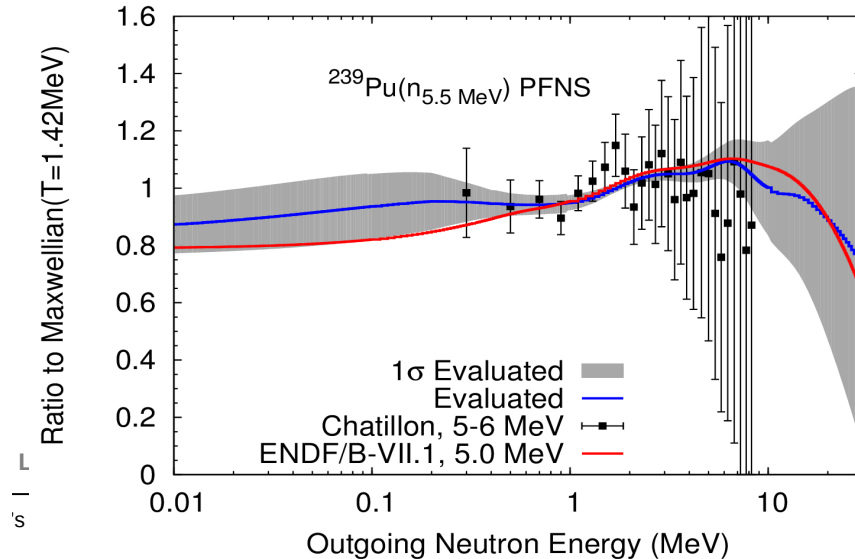
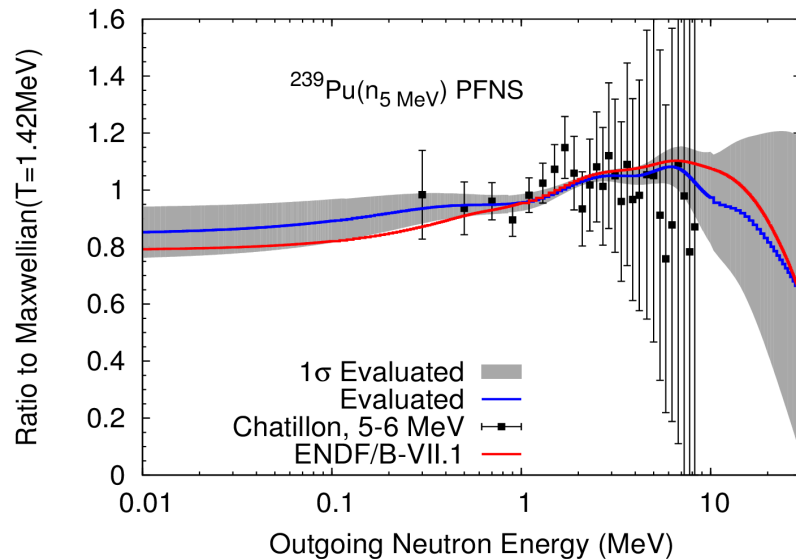
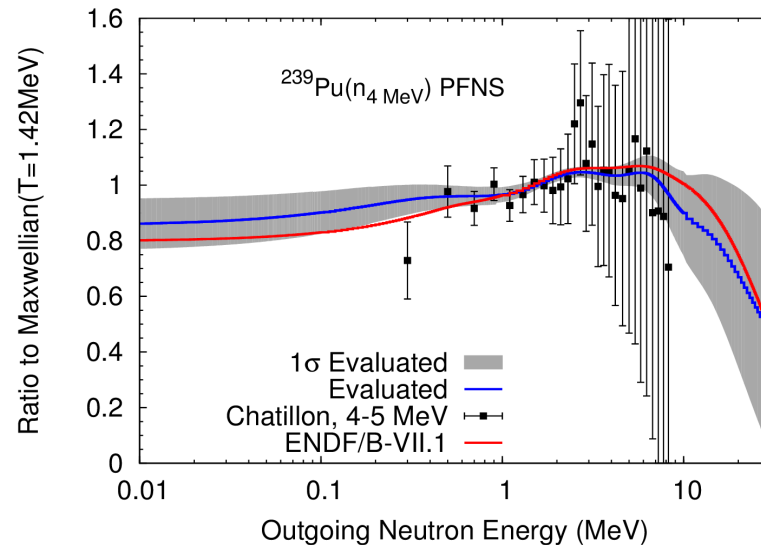
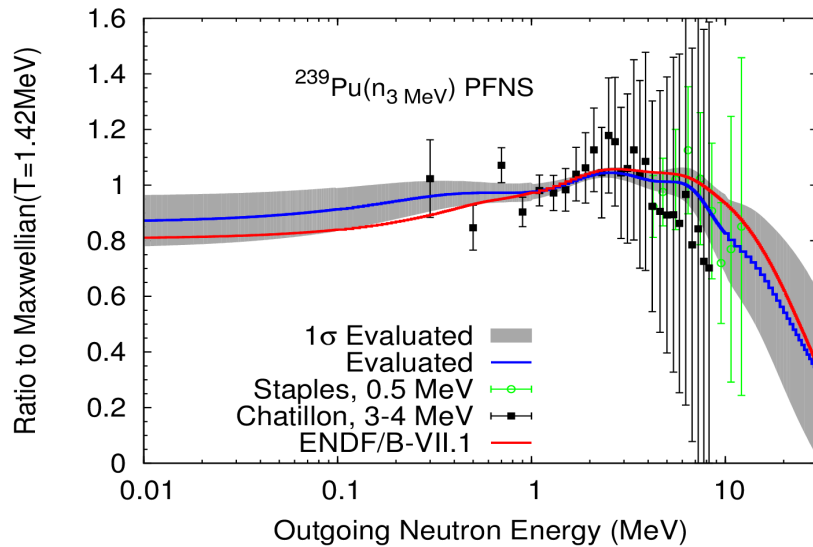


# Backup: All results I

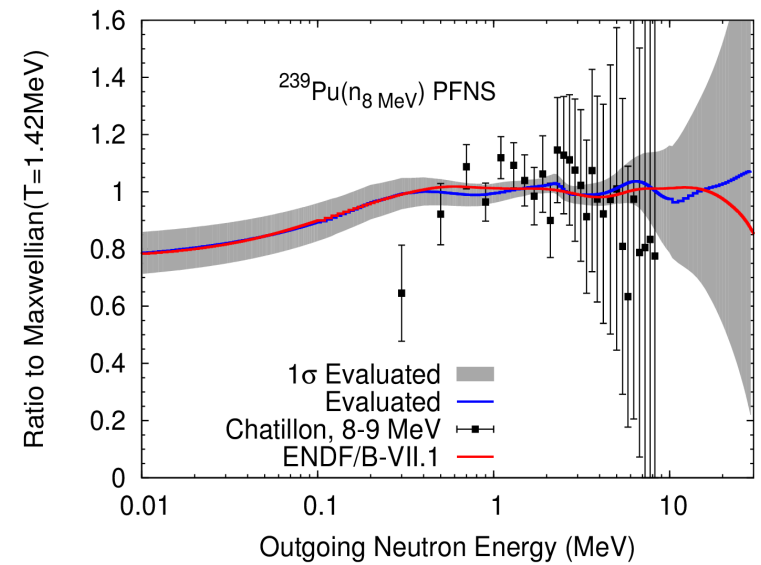
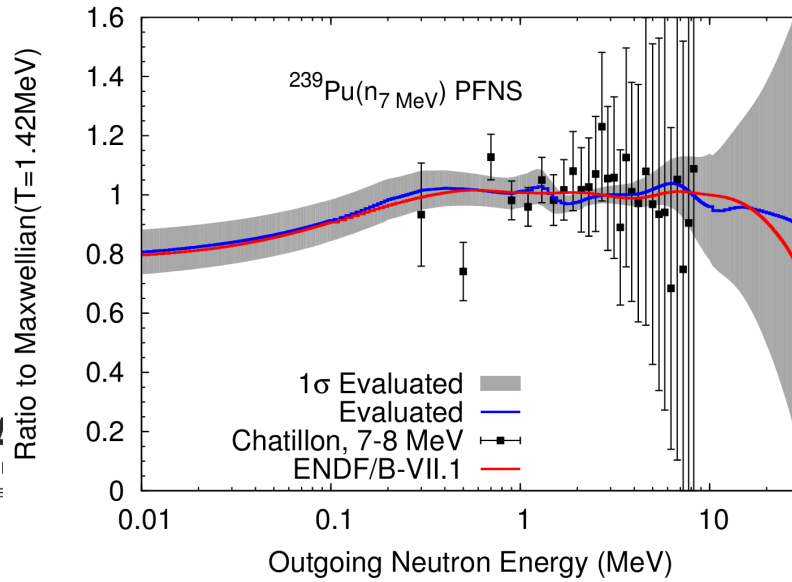
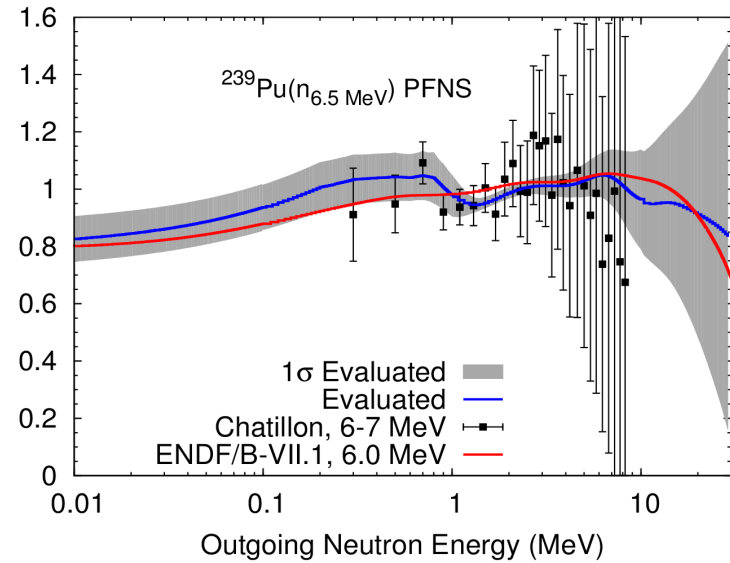
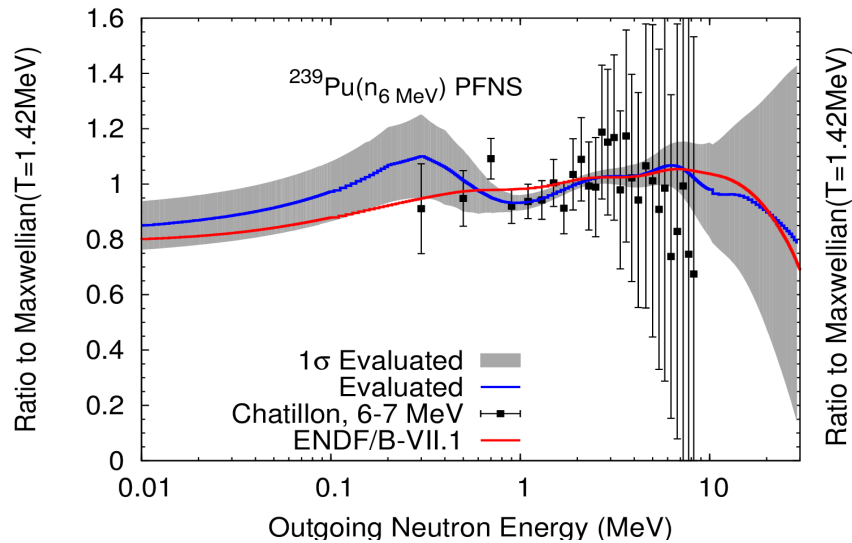




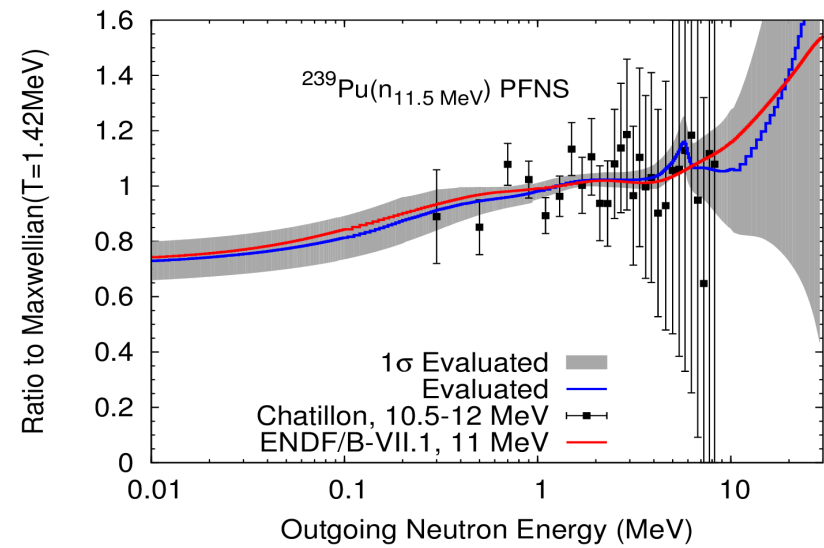
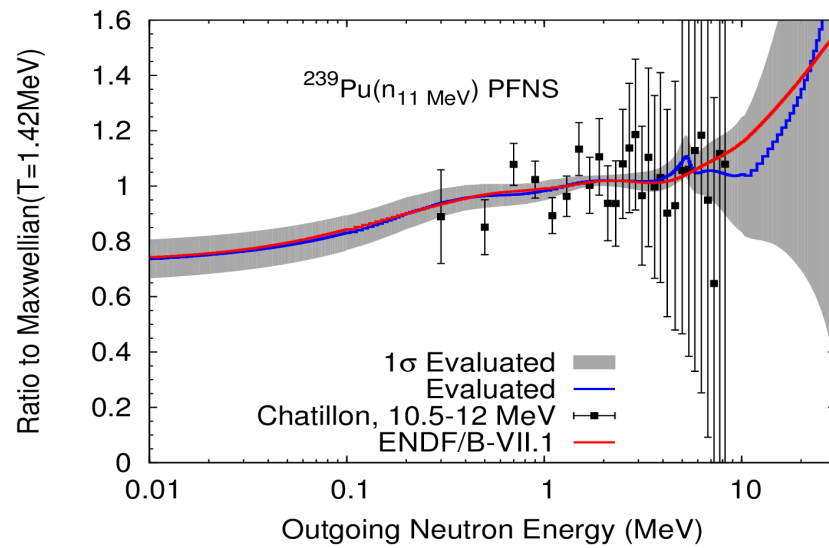
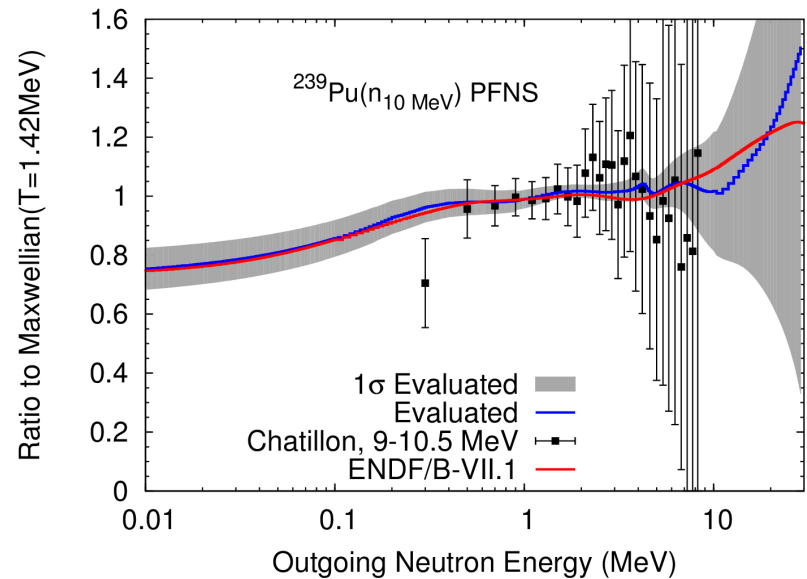
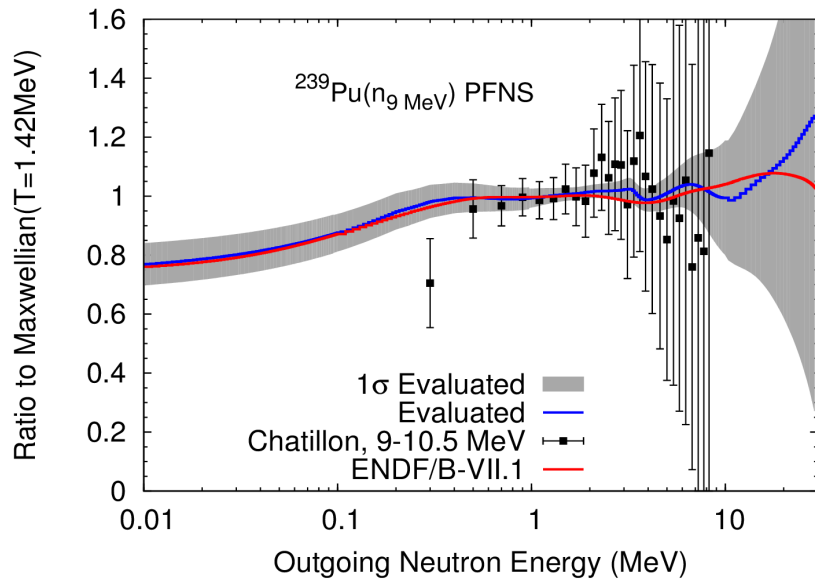
# Backup: All results II



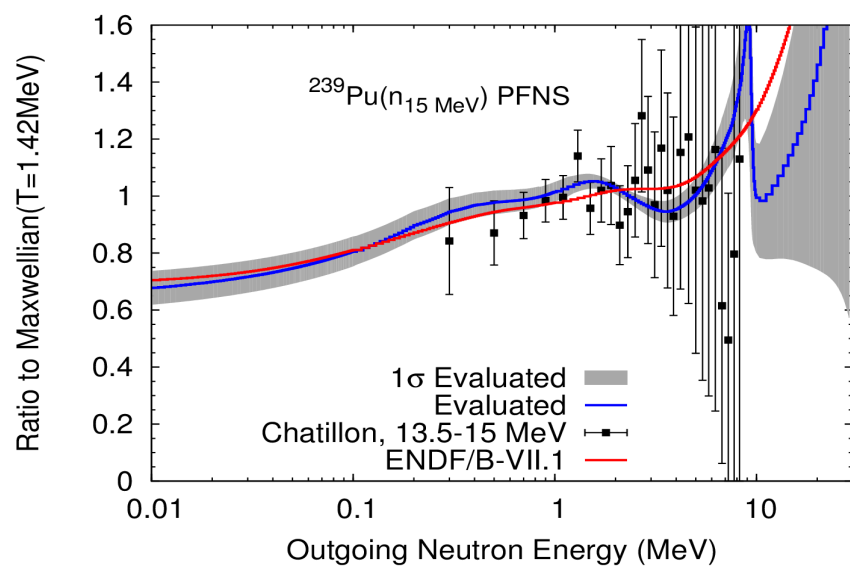
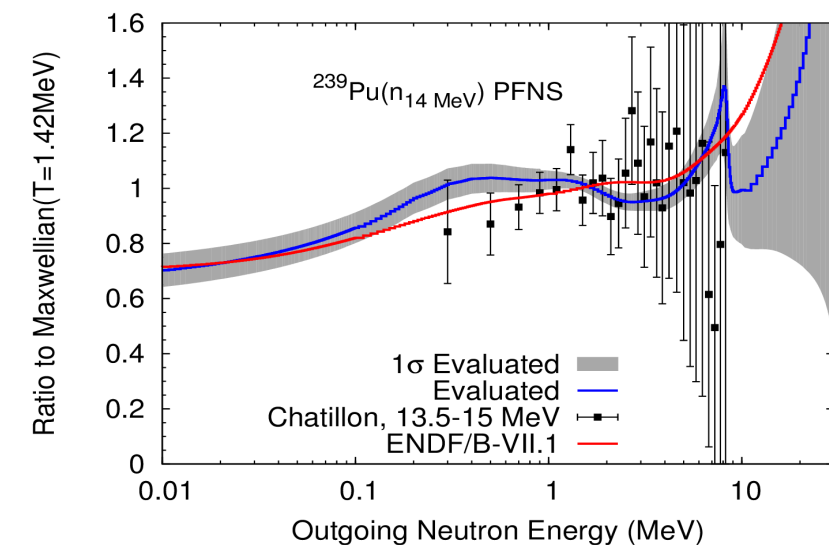
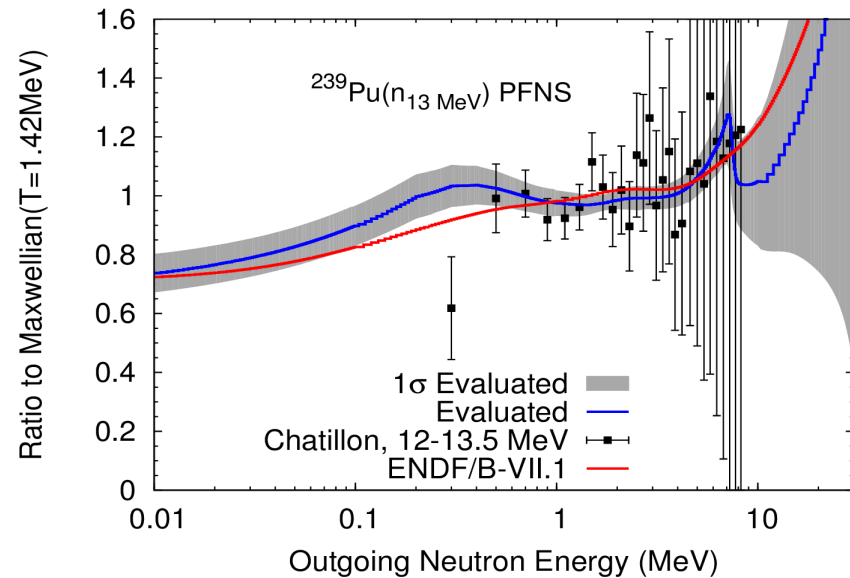
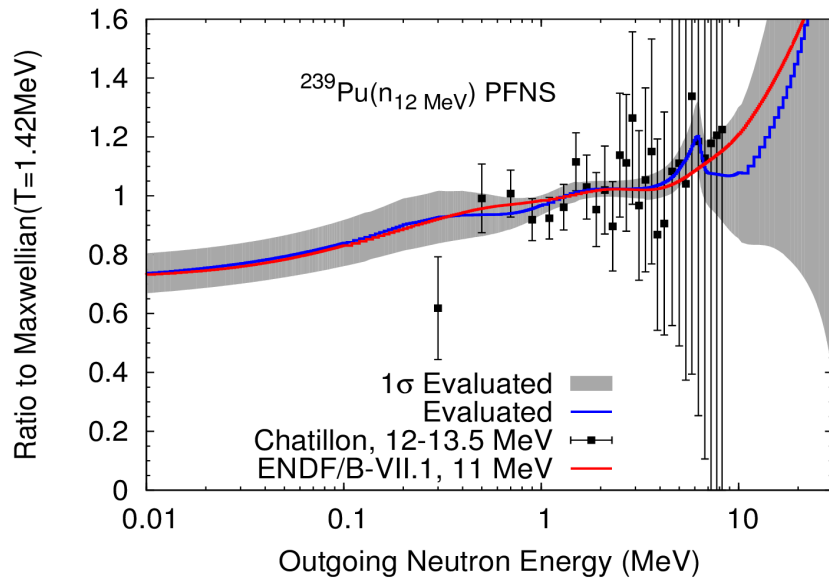
# Backup: All results III



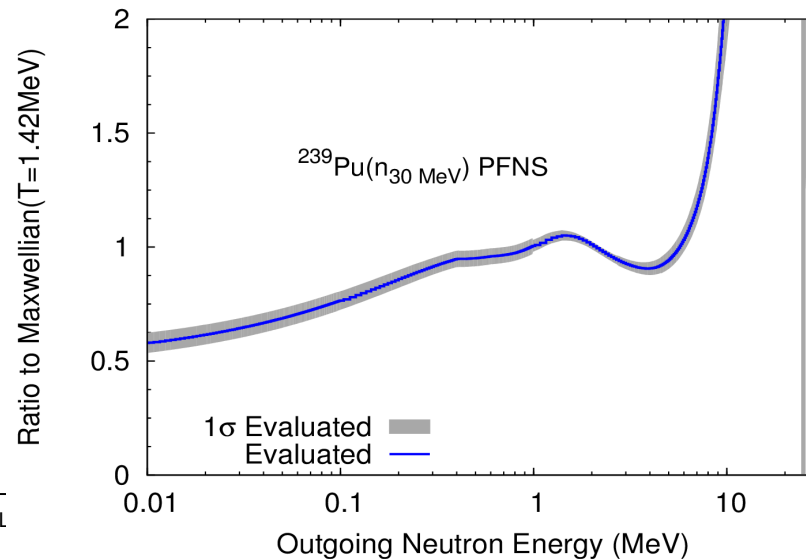
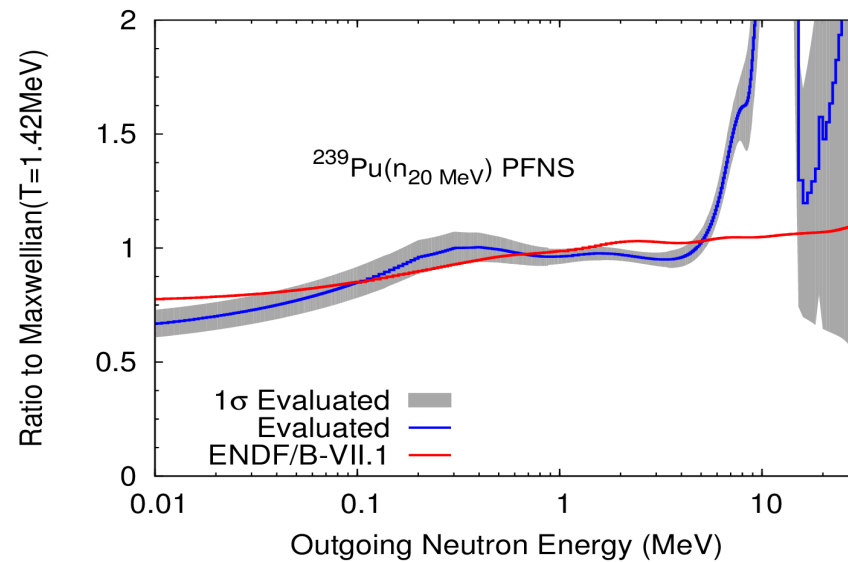
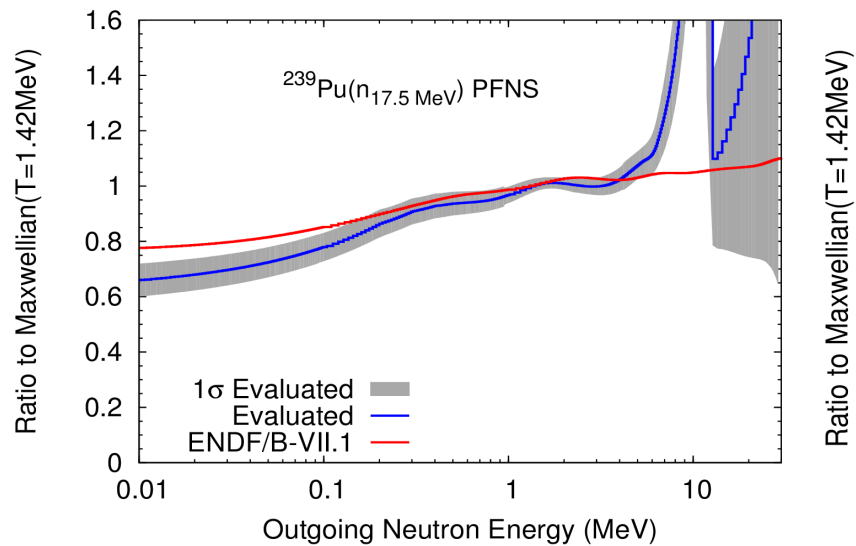
# Backup: All results IV



# Backup: All results V



# Backup: All results VI



# Backup: All results VII

